Reproductive biology of chub mackerel *Scomber japonicus* in Larache area, Moroccan North Atlantic coast*

by

Mohamed TECHETACH (1), José A. HERNANDO-CASAL (2),
Younès SAOUD (1) & Mohamed Hassan BENAJIBA (1)

ABSTRACT. - The reproductive biology of chub mackerel, *Scomber japonicus* (Houttuyn, 1782) was studied for the first time in Larache coast from January to December 2005. Using gonadosomatic index (GSI) and gonad macroscopic observation, spawning season was estimated to be from December to March and in June and July with a peak in January. The mean total length at 50% of maturity was 22.88 ± 0.42 cm for males and 23.01 ± 0.31 cm for females. Regarding sex ratio, there was a significant difference in the number of males and females. Seventeen females were used for estimating fecundity. The mean fecundity (F) was 285,704 oocytes, ranging from 77,621 to 465,712. The mean relative fecundity was estimated to be 1567 eggs per gram body weight without ovary. The relationships between absolute fecundity [F x 1000] and total length [F = 651.95 Ln(TL) – 1841.1] and with somatic weight without ovary [F = 196.91 Ln(W) – 709.53] were of the logarithmic type.

RÉSUMÉ. - Biologie de la reproduction du maquereau *Scomber japonicus* de la région de Larache, Atlantique Nord marocain.

La biologie de la reproduction du maquereau espagnol, *Scomber japonicus* (Houttuyn, 1782) a été étudiée pour la première fois au niveau des côtes de la région de Larache. La détermination de la saison de ponte est basée sur le suivi mensuel de l'indice gonadosomatique et les stades de maturité macroscopiques. Cette saison a lieu de décembre à mars et en juin-juillet avec un pic d'activité de reproduction enregistré en janvier. La taille totale moyenne à laquelle 50% des individus sont matures, a été estimée à 22,88 ± 0,42 cm pour les mâles et 23,01 ± 0,31 cm pour les femelles. Le sex-ratio montre une différence significative entre la proportion des mâles par rapport aux femelles. Dix-sept femelles ont été utilisées pour l'estimation de la fécondité. La fécondité moyenne (F) est de 285 704 ovocytes et elle est comprise entre 77 621 et 465 712 ovocytes. La fécondité relative moyenne a été évaluée à 1567 ovocytes par gramme de femelle sans ovaire. La relation entre la fécondité absolue [F x 1000] et la taille totale [F = 651,95 Ln(TL) – 1841,1] et avec le poids total sans ovaire [F = 196,91 Ln(W) – 709,53] est de type logarithmique.

Key words. - Scombridae - *Scomber japonicus* - Morocco - Larache coast - Reproduction.

The chub mackerel *Scomber japonicus* Houttuyn, 1782 is a cosmopolitan pelagic species that inhabits warm and temperate costal waters of the Atlantic, Indian, and Pacific oceans and adjacent seas. It is found in the continental slope from the surface to the depth of 300 m and reaches its deepest levels during the day (Lozano-Rey, 1952; Collette and Nauen, 1983).

Mackerel landings recorded at the coast of Larache in the year 2005 amounted to 8154 tonnes for a value of 12 Mdhs, representing 50% of the total quantity of fish production and 12% in terms of value (MPM, 2005) which gives a great importance to both biomass and value. At the port of Larache, the landings are recorded on behalf of mackerel without distinction between Atlantic mackerel, *Scomber scombrus* L., and chub mackerel, *Scomber japonicus*.

Despite the mackerel socioeconomic and ecological interest, works dealing with the biology of this species in the Moroccan Atlantic are very scarce. In contrast, several aspects of the reproduction of this species were analysed in various areas of the Atlantic (Razniewski, 1967; Lorenzo, 1992; Lorenzo and Pajuelo, 1993). The knowledge of the characteristics of mackerel reproduction biology is an important basis for understanding the dynamics and rational management of this species.

The objectives of the present study are to determine the size at the first maturity of males and females, the varying maturation gonads, the spawning season, the estimation of the absolute fecundity and the comparison of these results with previous works.

(1) University of Abdelmalek Essaadi, Science Faculty, Laboratory of Applied Biology and Pathology, PO Box, 2121 Tetouan, 93002, MOROCCO. [mtechetach@gmail.com]

(2) Universidad de Cádiz, Facultad de Ciencias del Mar y Ambientales, Departamento de Biología, Puerto Real, 11510, Cádiz, SPAIN.

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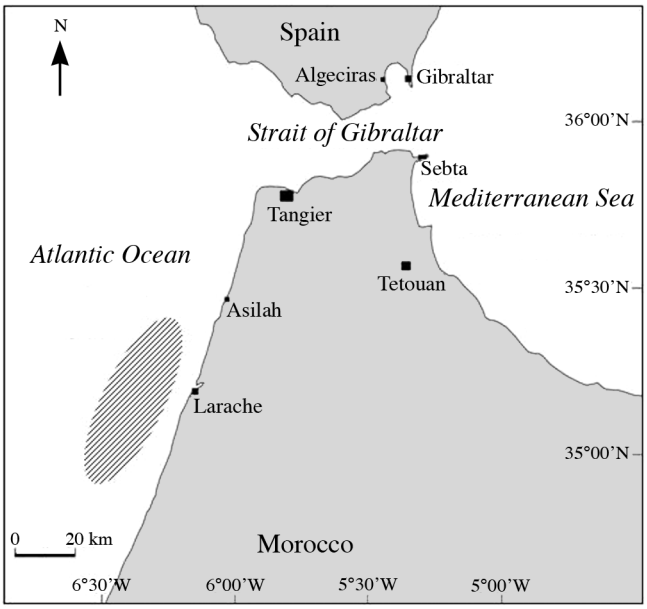

Figure 1. - Map of Larache region in north-eastern Moroccan Atlantic Ocean showing the fishing area.

MATERIAL AND METHODS

Samples of chub mackerel were collected in Larache waters from purse seine catches (Fig. 1). A total of 967 chub mackerel (*S. japonicus*) was collected between January and December 2005. Specimens were obtained from weekly sampling. In the laboratory, both the total length (Lt, mm) and body weight (W, 0.1 g) of each fish were recorded. The gonads were dissected from the fish and weighed to the nearest 0.0001 g, while sex (male, female) was determined by visual examination of the gonads.

The maturity stages in the chub mackerel were determined macroscopically according to the scale of Arriaga *et al*. (1983). It includes five stages of sexual maturity for both sexes. They are as follows: stage I, immature-virgin; stage II, maturing virgin or recovering spent; stage III, maturing; stage IV, ripe; stage V, spent.

Temporal patterns of female and male gonad development were described using the gonadosomatic index according to the formula of Anderson and Gutreuter (1983):

$$\%GSI = \text{Gonad weight (g)} / \text{Body weight (g)} \times 100$$

During the spawning season, the proportion of mature females and males by 1 cm total length classes was used to estimate the size at the first maturity, of which 50% of the fish are mature. These were obtained by fitting a logistic equation as described by Ashton (1972) and applied to other species by Saborido and Junquera (1998):

$$P = e^{(a + b \times TL)} / 1 + e^{(a + b \times TL)}$$

where *P* is the predicted mature proportion; while *a* and *b* are model parameters; and TL is the total length in cm. The following logarithmic transformation was used:

$$Ln[p / (1 - p)] = a + b \times TL$$

A statistical program Statistica 6.0 was used to calculate the parameters *a* and *b*. Length at the first maturity (L_{50} = length of 50% mature) was obtained as the ratio of the coefficients (-a/b), by substituting P by 0.5 in logarithmic transformation equation.

The sex ratio (female:male) was determined for the total sample and for each size class. A χ^2 goodness of fit test was undertaken to compare if the proportion of males and females was significantly different from 1:1.

For the estimation of mackerel fecundity, the sample was excised from the big lobe of the left ovary, weighed (WS_{ovary}, 0.0001 g) and fixed by Gilson's liquid. The number (N) of vitellogenic oocytes in the subsample was counted. Absolute fecundity (F) was then calculated using the gravimetric method (Murua *et al*., 2003; Hunter and Goldberg, 1980) by the formula:

$$F = (W_{ovary} / WS_{ovary}) \times N$$

RESULTS

Seasonal fluctuations of gonadosomatic index (GSI)

GSI ranged from 0.003 to 9.03 for females and from 0.001 to 11.5 for males. The monthly variation in the mean GSI is presented in figure 2. A similar pattern was evident for female and male fish. The GSI showed the high values from November to March and peaking in February for males and in January-February for females. In addition, the other highest values were observed in June-July for females and only in June for males.

Seasonal changes of gonad maturation

The monthly distribution of the proportion of maturity stages of *S. japonicus* revealed a seasonal variation (Fig. 3). The early presence of stage III (maturing) was observed for both sexes in November. The stage IV (ripening) appeared in December and lasted for both sexes until March. This stage IV was also found in June and July for females and only in June for males.

Size at maturity

The chub mackerel is considered as reproductively active species specifically at the maturity stages III, IV and V and its size ranged from 18.9 to 37.1 cm for males and from 19.6 to 35.5 cm for females. The parameters obtained from fitted logistic regression to the proportion of mature males and females by length were resumed in table I. The maturity curve fit significantly to the observed data ($\chi^2 = 68.21$, $p < 0.001$ for males and $\chi^2 = 66.58$, $p < 0.001$ for females). The size at the first sexual maturity (TL_{50}) was 22.88 ± 0.42 cm for males and 23.01 ± 0.31 cm for females (Fig. 4).

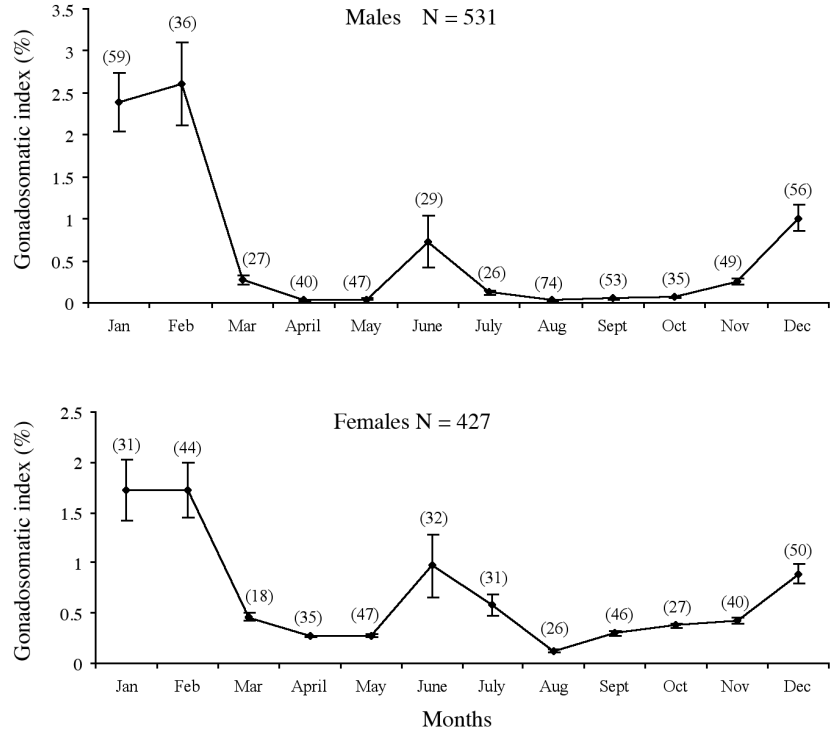

Figure 2. - Monthly changes of gonadosomatic index (GSI) for males and females *Scomber japonicus* during year 2005. Vertical bars indicate standard errors. Numbers in parentheses indicate sample size.

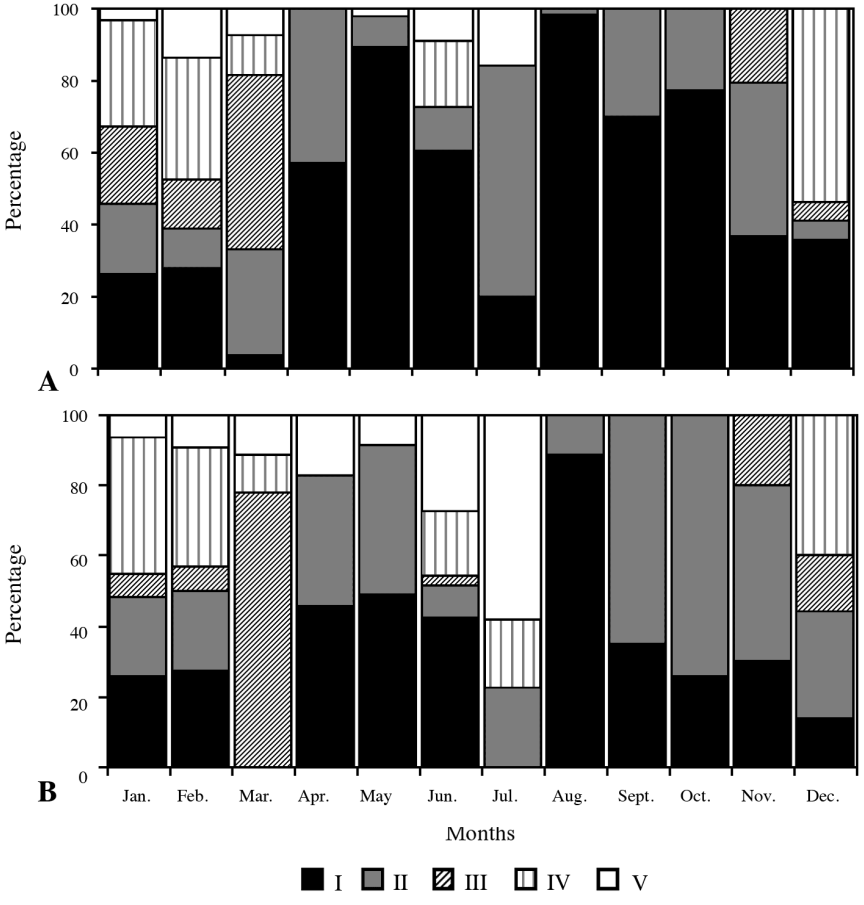

Figure 3. - Monthly variation in relation to the maturity stages I-V of *Scomber japonicus* during year 2005. **A**: Males; **B**: Females.

Table I. - Estimated parameters for TL_{50} for males (**A**) and females (**B**) of *Scomber japonicus*.

A

Parameters	a	b
Estimate	-7.7851	0.3402
Standard error	1.1332	0.0508
t(249)	-6.8698	6.8311
p-level	0.0000	0.0000
Numbers of males = 251		
TL_{50} (-a/b) = 22.88		
$R^2 = 0.84$		

B

Parameters	a	b
Estimate	-13.8246	0.6005
Standard error	1.8071	0.0792
t(249)	-7.6500	7.5842
p-level	0.0000	0.0000
Numbers of females = 233		
TL_{50} (-a/b) = 23.01		
$R^2 = 0.87$		

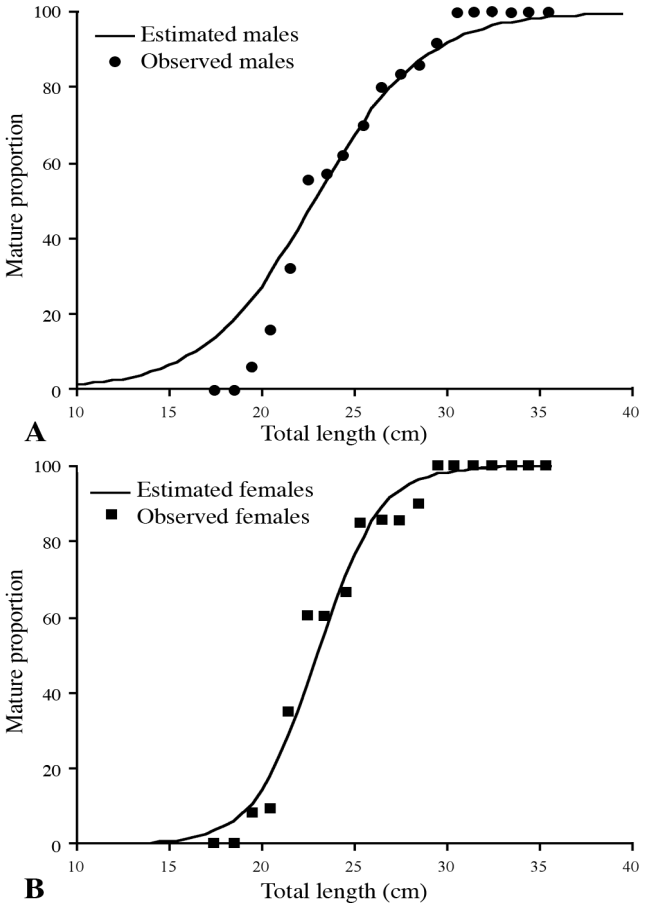

Figure 4. - Maturity acquisition of *Scomber japonicus*, captured in Larache area. **A**: Males; **B**: Females.

Sex ratio

A total of 967 specimens was sampled during the study, 44% (429) were females and 56% (538) were males. The sex ratio (F:M) for the whole sample was 0.79:1, with the proportion of males significantly higher than that of females ($\chi^2 = 12.28$, $p < 0.001$). The sex ratio was not significantly different from1:1 for all the size classes except in sizes ranging between 19 and 21 cm, in which the preponderance of males over the females was significant ($\chi^2 = 10.77$, $p < 0.001$). Females predominated in the largest size classes (≥ 31 cm TL) (Fig. 5).

Fecundity

During the reproductive season, 17 ovaries from females at stage IV of the sexual maturity ranging from 20.5 to 31.4 cm in length and from 59.52 to 386.37 g in weight were selected for fecundity estimation. Fecundity varied from 77,621 to 465,712 oocytes corresponding to the female total length of 19.6 and 33 cm, respectively. The mean absolute fecundity was 285,704 oocytes for the mean length 26.42 cm and the mean relative fecundity of *S. japonicus* was 1567 eggs per gram body weight without ovary. The fecundity was correlated with the length and weight of fish without ovaries. The larger females showed a higher fecundity. The relationship between fecundity (F x 1000) and the total length (TL) (Fig. 6A) was:

$$F = 651.95 \text{ Ln}(TL) - 1841.1$$
$$(R^2 = 0.78, p < 0.001, N = 17)$$

The relationship between fecundity (F x 1000) and the total weight (W) without ovaries (Fig. 6B) was:

$$F = 196.91 \text{ Ln}(W) - 709.53$$
$$(R^2 = 0.81, p < 0.001, N = 17)$$

The correlation coefficients calculated between fecundity and total length and total weight without ovary showed high and significant values ($p < 0.001$). So, a logarithmic model described well an increase in absolute fecundity.

DISCUSSION

Information regarding the reproductive biology of chub mackerel is very rare in the coast of Morocco. In this framework, the present paper will be considered essential for the knowledge and the management of this resource.

The monthly changes of GSI values and the seasonal distribution of maturity stages of *S. japonicus* suggested that the spawning activity occurred in two periods; the first period is from December to March for both sexes and the second period is June-July for females but this period for males is limited at June due to the absence of the running stage in this month. The first period of spawning reported by the present study was observed by Habashi and Wojciechowski (1973) in the Moroccan coasts. Chub mackerel around the Canary

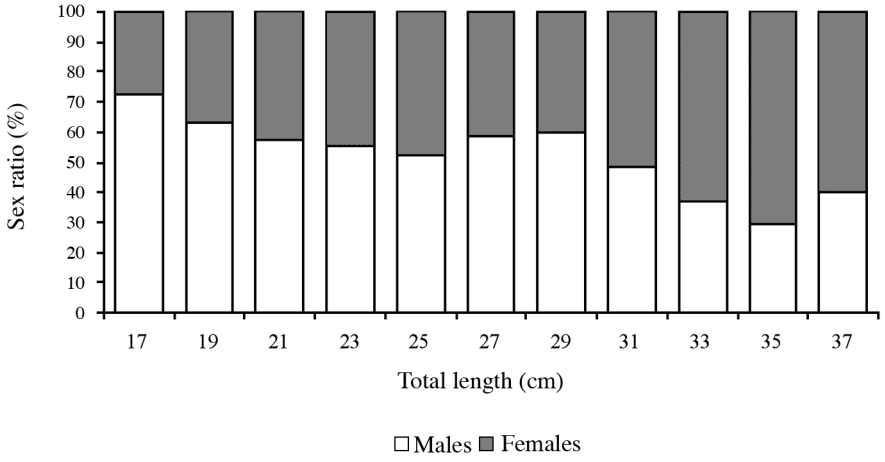

Figure 5. - Sex ratio (%) of *Scomber japonicus*, as a function of the total length (cm).

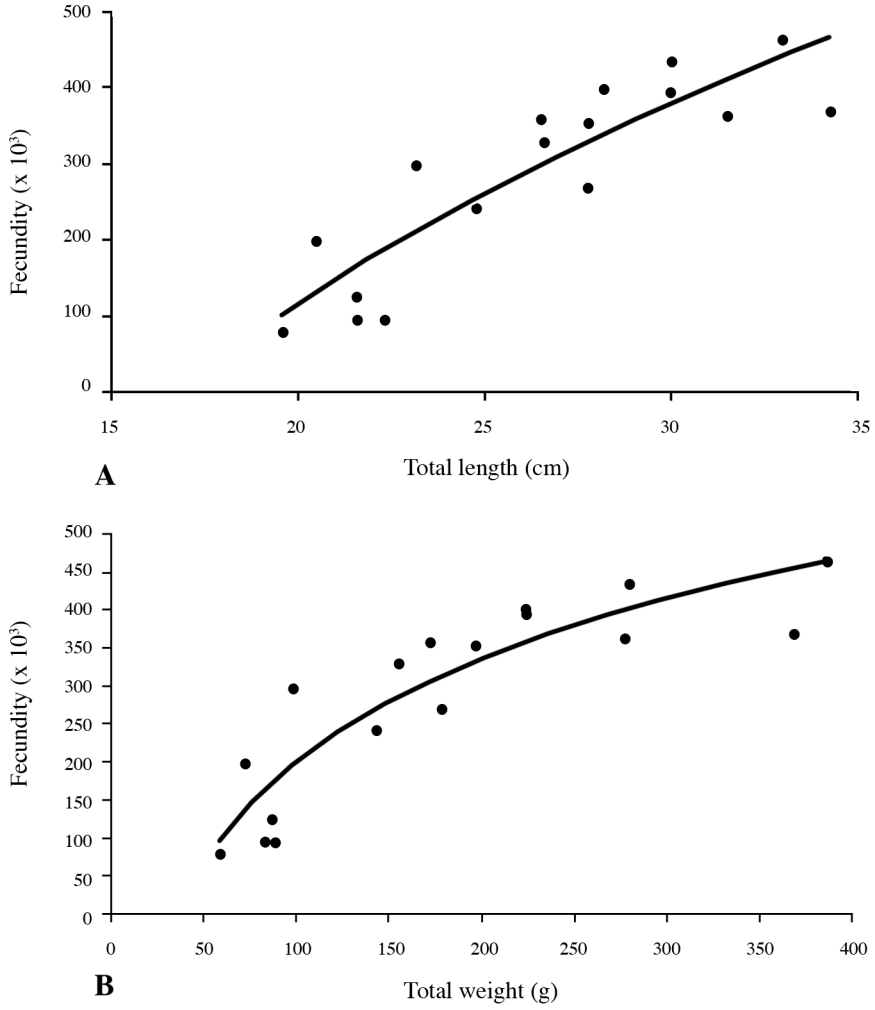

Figure 6. - Absolute fecundity related to total length (cm) (**A**) and to total weight (**B**) for *Scomber japonicus* in Larache area.

Islands spawns from December to March with the maximal activity in December and January (Lorenzo, 1992). The spawning of chub mackerel is between April and June in Portugal waters. The spawning of this species seems to be related to water temperature. The optimum temperature for spawning is 18-19ºC (Collette and Nauen, 1983). In South Africa, chub mackerel spawns in winter and early spring (Baird, 1977) when inshore current spurred by north westerly winds bring relatively warm water (14 to 15ºC) and season of breeding is defined as June-September (Crawford,

1981). In the Mediterranean, the breeding season of *S. japonicus* is between December and January for the first period and between June and August for second period in Tunisian waters (Hattour, 2000). In Libya waters, the spawning season extends from April to June (Giama, 1994).

The males attain the length at the first maturity (L_{50}) at a slightly lower size than females, 22.88 and 23.01 cm, respectively. The smallest reproducing individuals were 18.9 cm TL for males and 19.6 cm TL for females. Similarly, in Senegal-Mauritania zone, they reached sexual maturity at 22.2 cm, corresponding to 2.2 years old (FAO, 1987). Knaggs and Parrish (1973) pointed out that males mature earlier in life than females. Along the northwest African coast, many mature specimens were of a size of 16 to 22 cm TL (1 year old), while most of the individuals between 20 and 30 cm (2 year old) were mature. In Argentina, Angelescu (1979) reported that the length of the first maturity fluctuates between 18.5 and 23.5 cm TL. Around the Canary Islands, the mean size of the first maturity of chub mackerel was 19.85 cm TL for males and 19.9 cm TL for females and all adults are mature at 26 cm TL. This could indicate that for some species, the size at the first maturity can change enough from some localities to others due to the different oceanographic conditions and to the proper character of every population (Lorenzo, 1992; Lorenzo and Pajuelo, 1993). The chub mackerel of Tunisia are reported to reach the L_{50} (Fork size) at 18.9 cm for males, 18.3 cm for females and 18.9 for the combined sex, corresponding to the beginning of second year old (Hattour, 2000). From the management point of view, it is necessary to fix the minimum size of the capture which is equal or higher than the size at the first maturity for the rational exploitation of this important resource.

The dominance of males observed in the Larache coast was also found for chub mackerel in the waters of southern Brazil (Seckendorff and Zavala-Camin, 1985). In contrast, Lorenzo (1992) noted a slightly dominance of the female sample in the Canary Islands with no significant prevalence. The sex ratio 1:1 was reported in the Hellenic seas (Kiparissis *et al*., 2000) and in waters of Libya (Giama *et al*., 1987). But in Tunisian waters, Hattour (2000) observed a significant dominance of females. In South Africa, Baird (1978) found that the sex ratio was close to 1:1 with a slight predominance of females. The sex ratio of 1:1 was also found for chub mackerel in the Pacific Ocean (Schaefer, 1980; Mendo, 1984). In winter and during the spawning period, the sex ratio varies among chub mackerel schools (Watanabe, 1970). The dominance of males may be due to the difference in the spatial distribution between males and females. The difference in sex ratio between geographic zones is perhaps related to migratory behaviour of the females during the spawning season and their catchability changes.

Absolute fecundity was a logarithmic function of total length and of body weight. The correlation between the fecundity and both of total length and fish weight were significantly positive. Absolute fecundity estimates were lower than those obtained for chub mackerel in the Sea of Japan, where a single female of 32 cm standard length produces 441,795 eggs, and a female of 46 cm produces 1,859,173 eggs (Lushkareva, 1960). Song *et al*. (1988) found that the individual fecundity of the chub mackerel of northern Yellow Sea increases exponentially with weight, fork length and age, ranging from 195,400 to 900,400 eggs, and averaging 531,600 eggs.

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